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SOME DEVELOPMENTS IN THE WATER POLLUTION RESEARCH PROGRAM OF THE PUBLIC HEALTH SERVICE.*

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The headquarters station of the Public Health Service for research in matters pertaining to water, sewage and stream pollution, now a section of the National Institute of Health, is located at Cincinnati, Ohio. This type of research has been a gradual development of the original pollution and natural purification study of the Ohio River organized and directed by the late Dr. Wade H. Frost. The same building then occupied is still in use but enlarged activities have rendered it inadequate. An allotment of $275,000 from the general public building fund has been made for a new laboratory building, construction of which will be started on a new site as soon as agreements for acquirement of the new 8 acre property are consummated and plans can be completed.

The research work in which the station is engaged is concerned with sanitary problems pertaining to the uses of water, its pollution and purification. Recently the fundamental mechanism of the biochemical oxidation of organic matter, as it functions in biological methods of sewage treatment, has been under observation. Considerable experimental work has been completed concerning determination of the rates of oxygen withdrawal from

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flowing water by underlying sludge deposits. A field study of the sanitary condition of the Scioto River as affected by installation of modern methods of treatment of contributed sewage has been completed. A nation-wide continuing census of water and sewage treatment plants has been inaugurated. The station is also conducting an extensive laboratory study of the sanitary condition of the waters of the Ohio River and its tributaries as a part of the pollution survey being undertaken jointly by the Public Health Service and the U. S. Army Engineer Corps.

Sewage Treatment Studies. The primary objective of this research has been to determine the factors that impair the efficiency of the activated sludge method of sewage purification. Exploration of these interfering agencies has led to an investigation of the basic mechanism of the biological oxidation process of organic matter in liquids and the conditions which stimulate or retard its progress. It has been found advisable to work with individual parts of the complex biological and biochemical principles comprising the activated sludge process and to study the functioning of some of these separate parts free from interference and under controlled environment, and then to gradually assemble these parts and observe the resulting effect. Following this procedure and employing apparatus developed for observing the rate of oxygen use[1] and using pure cultures obtained from individual cells isolated from activated sludge have made it possible to develop certain conclusions concerning the oxidation process.

The predominant type of organisms in activated sludge appear to belong to the zoogleal group of bacteria. These bacteria, when aerated in pure culture in a clear synthetic medium or in sterilized sewage, produce a growth which exhibits the characteristic properties of activated sludge such as flocculation, rapid settling, and clear supernatant with high rates of oxidation and total purification of the contained soluble organic matter.(2) Following this lead, it has been possible to demonstrate the exceedingly high rate of oxidation of organic matter effected by activated sludge in comparison with the removal rate of biochemical oxygen demand (B.O.D.) regularly observed in streams or in the dilution process. It appears that the massed or clumped zoogleal bacteria maintained by proper aeration necessary for their rapid growth, explains the high rate of biochemical oxidation obtained in the activated sludge process.(3)(4) Pursuing this line of study further, the similarity of the clarification mechanism of normal activated sludge and of that occurring with the elementary pure bacterial culture sludge has been demonstrated. Moreover, it has been possible to trace the component rates of total purification, including the oxidation rate as distinguished from those of net adsorption and synthesis of organic matter occurring in the activated sludge process.(5) Further studies are now in progress which appear to demonstrate the close similarity in characteristics and functions of the zoogleal bacteria as obtained from activated sludge flocs and from the slime coatings of sewage sprinkling filters.

The problem of developing some practicable method for ascertaining quickly the condition of activated sludge by the plant operator has been given consideration. The B.O.D. reduction test appears to be an insensitive indicator of the change in purification capacity of activated sludge. The quantity of oxygen used per gram of suspended matter during a short aeration period of the sewage-sludge mixture was found to be a better index of activated sludge condition.(6)

Aside from devices for observing the rate of oxygen used, determination of the capacity of activated sludge for glucose removal from the substrate appears to offer some promise as a sludge index, as well as an explanation of the mechanism of removal of soluble organic constituents in sewage. Studies of the ash content of both pure culture zoogleal and normal activated sludge have indicated no definite relation between ash volume or composition and oxidation or total purification capacities.

The relationship of fungus growths of the Sphaerotilus type to sludge bulking are being studied. Our observations appear to indicate that Sphaerotilus requires very little oxygen for its growth, is therefore of small value as an oxidizing agent and flourishes best when conditions detrimental to the normal growth and functioning of the zoogleal bacteria prevail in the sludge-sewage mixture. The previous work of Ruchhoft has been confirmed concerning the stimulation of Sphaerotilus growth afforded by carbohydrates in the sewage liquor. Results indicate that this growth stimulation is not directly

proportional to the amount of mono- or di-saccharoses present, but is an indirect stimulus by a substance or substances present when excessive amounts of carbohydrate material upset the usual biological balance in normal activated sludge.

In research of this nature, development of suitable methods and exploration of incidental observations are generally necessary and profitable. Thus, it has been determined that the modified azide procedure[7] is of value in increasing the accuracy of the B.O.D. test in the presence of nitrites. It has also been discovered that the Winkler method for determination of the B.O.D. of river muds may be quite inaccurate owing to interference of contained substances such as insoluble sulphides with the reagents but that many of these interfering compounds can be removed by coagulation previous to beginning the test for dissolved oxygen. Again, the dissolved oxygen saturation value of sewage was found to be approximately equal to that of clear water.[8]

Stream Oxidation Study. Experimental studies have been in progress over a considerable period designed to develop practical methods for evaluation of the capacities of flowing streams for natural oxidation of sewage and other organic wastes. Past studies have shown that the rate of natural oxidation of organic materials in solution and suspension in a natural body of water can be measured directly by the ordinary B.O.D. test of representative samples. The most uncertain element is the oxygen demand exerted by underlying sludge deposits which are not included in the water sample and are for this

reason extremely difficult to measure, both as to their extent and their rates of oxidation under the conditions in which they exist naturally. Starting with the development of a rational method for calculating the deoxygenating effect of sludge deposits based upon observations of the B.O.D. of the supernatant water[9] and proceeding to the explanation of formulae by which rates of oxidation and reaeration and the trend of the resultant oxygen curve may be calculated from observations of progressive changes in the biochemical oxygen demand and dissolved oxygen content of a polluted stream[10] the results of experimental work have been presented showing the effect of various factors on the oxygen depletion and reaeration rates occurring.[11] Later direct experimental evidence on the oxidation rates of river bottom sediments now awaits critical analysis and publication. A complementary study has indicated that the rates of reaeration of sewage polluted streams particularly when flowing at higher velocities are materially lower than reaeration rates of unpolluted waters.[12]

Scioto River Study. The evaluation of sewage treatment in definite terms of stream improvement has been the objective of a comprehensive field study of the sanitary condition of the Scioto River in Ohio during the past two years or more. The City of Columbus discharges its liquid wastes to the Scioto River. The original sewage treatment plant was entirely inadequate and obsolete and has been recently replaced by a modern one of the activated sludge type. Observations of the bacteriological, biological and biochemical condition of the

river waters and channel sediments were undertaken for a complete year throughout the 100 mile river stretch below Columbus, both prior to and following completion of the new sewage treatment works. The extensive analytical data are now being assembled and critically analysed in preparation for publication of the results obtained and the conclusions possible to be drawn. A preliminary review of the data indicates that although the old Imhoff tank Sprinkling filter plant was entirely inadequate, the effect of this effluent on the river was not so detrimental as that discharged from the new plant when plain sedimentation only was employed during the first few months of its operation. However, when complete, activated sludge treatment was begun, a profound improvement in the sanitary condition of the stream promptly occurred. This improvement was definitely reflected in the bacteriological and plankton content and biochemical reactions of the water as well as in the animal life in the bottom sediments. Some incidental observations pertaining to stream biology and the verification of certain organisms as pollution indicators have been published.(13)(14)(15)

Inventory of Water and Sewage Treatment Plants. Although the recently inaugurated continuing census of water and sewage treatment plants and stream pollution conditions throughout the United States is not a strictly fundamental research activity, it is intended to serve as a useful tool to locate problems in these fields and record progress made in their solution as well as to serve as an aid to the engineering divisions of State Health Departments. Work is in progress on the collec-

tion of basic data on each individual plant. As soon as sufficient data have been made available by the States, it is proposed to summarize them for publication and to revise such publications periodically. It is hoped that eventually the Public Health Service may act as a clearing house for the exchange of such information and thereby relieve the individual states of some requests for data of this nature.

Ohio River Pollution Survey. Legislation enacted by the 75th Congress, first session, directed the Secretary of War to have made a comprehensive survey of the pollution of the Ohio River and its tributaries for determination of necessary corrective measures. Provision was also made for obtaining the cooperation and assistance of the Public Health Service in this activity. This survey is now in progress jointly by the U. S. Engineer Corps and the Public Health Service. To the Stream Pollution Investigations Station has been assigned the direction and conduct of all analytical work of the Survey. Although this assignment is not primarily one of research, but rather one of fact finding, it does afford some possibilities of employing the assembled data for critical study. The central third of the watershed at present under observation extends from the mouth of the Kanawha at Point Pleasant, West Virginia, to the mouth of the Kentucky at Carrollton, Kentucky, including the tributaries within this river stretch of about 280 miles and comprises a watershed area of over 30,000 square miles. It is proposed to cover the upper section of the watershed in 1940 and the lower third in 1941.

The central laboratory for this field study is located at Cincinnati, to which point samples are brought by motor boats and automobiles from accessible main river sampling stations and tributaries. The upper section of this river stretch and tributary area is served similarly by a completely equipped floating laboratory. The fringes of the watershed not readily accessible to the two large laboratories are being covered by mobile laboratory units moving from place to place. Coincidental with the analytical work, the Public Health Service is collecting detailed data pertaining to the sources, nature and extent of pollution contributed throughout the watershed.

A supplementary part of this Ohio River Study is an epidemiological and bacteriological investigation now in progress of the endemic and epidemic occurrence of intestinal disorders which may be water-borne. Such outbreaks of undetermined origin, are occurring with increasing frequency and while many of them have certain characteristics which cast suspicion on the drinking water supply, the causative factors are frequently obscure.

Miscellaneous activities. In the conduct of any research program opportunities are always presented for exploring some interesting problems more or less directly related to the main objectives. In our bacteriological laboratories the enumeration of the coliform group of organisms in water samples comprises an appreciable portion of the routine work. The possibility of making direct counts of this group on some solid differential medium is being investigated. The results of such

plate counts on duplicate samples from a large variety of sources are being correlated with those obtained by the standard methods dilution procedure. The data thus far accumulated appear to indicate that the direct counts on brilliant green lactose bile agar are sufficiently accurate to justify serious consideration of this shortened procedure when the density of coliforms in the sample is sufficient to provide for accurate plate counts.

In the coverage of certain parts of the Ohio River watershed an opportunity was afforded to explore the plankton life existing in the acid mine waters draining from coal mines. It was found that such microscopic life was restricted to only a few specific forms.(16)(17)

The methods of preparation of plankton specimens for microscopic examination and the changes in appearance of some of them induced by formalin used for their preservation has also been the subject of a separate publication.(18) Another interesting study has been an endeavor to evaluate the contribution of dissolved oxygen contributed to water by a definite species of algae.(19)

The results of the research work of the station are generally published in the Public Health Reports and are usually available in the form of reprints. Certain of the technical papers pertaining to sewage research are printed simultaneously in Sewage Works Journal or separately in appropriate professional journals.

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